Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.5, No.2, June 2017, pp. 194~201
Available online at: http://pen.ius.edu.ba

Ceramic Wastes Usage as Alternative Aggregate in Mortar and Concrete

Gulden Cagın Ulubeyli[1], Turhan Bilir[1], Recep Artir[2]
[1]Department of Civil Engineering, Bulent Ecevit University
[2]Department of Metallurgical and Materials Engineering, Marmara University

Article Info

Article history:

Received May 29th, 2017
Revised June 15th, 2017
Accepted June 17th, 2017

Keyword:

Aggregate
Ceramic Waste
Concrete
Durability Properties
Mechanical Properties

ABSTRACT

In the ceramic industry, huge amounts of wastes are generated during manufacturing and transportation processes. In order to decrease the need for landfill areas and increase environmentally harmful effects of such wastes, this industry is under pressure to finding effective ways for recycling its wastes and by-products. In addition, the construction industry requires new sources of aggregates due to running out of conventional virgin aggregates, saving energy, and protecting the environment. Therefore, recently, ceramic wastes are often used as coarse and/or fine aggregate both in mortar and concrete. In the present study, effects of using ceramic wastes as coarse and/or fine aggregate on the engineering properties of mortar and concrete are evaluated. These engineering properties are listed and compared according to their mechanical and durability properties. Reviewing of previous studies related with this subject in literature and discussion all results of the studies are conducted as the methodology of this study. Consequently, it was found out that the use of waste ceramic in the conventional concrete or mortar mix as fine/coarse aggregate is suitable as it can improve mechanical and durability properties of the concrete/mortar.

Corresponding Author:

Gulden Cagın Ulubeyli,
Department of Civil Engineering,
Bulent Ecevit University,
Farabi Campus, İncivez 67100, Zonguldak, Turkey.
Email: caginulubeyli@beun.edu.tr

1. Introduction

Recycling and reutilization of industrial waste and byproducts is a subject of great importance today in cement and concrete technology [1]. Especially ceramic wastes, which are durable, hard and highly resistant to biological, chemical and physical degradation forces, cannot be recycled by any existing process. The use of inorganic industrial residual products in the production of concrete will lead to sustainable ceramic industry ranges from 3% to 7% of daily production [2]. Therefore, construction industry can be the end user of all ceramic wastes and in this way can contribute to solve this environmental problem. The nature of construction industry, especially the concrete industry, is such that ceramic wastes can be used safely with no need for dramatic change in production and application process. On the other hand, the cost of deposition of ceramic waste in landfill will be saved and, on the other, raw materials and natural resources will be replaced, thus saving energy and protecting the environment [3].
In the present study, the effects of ceramic wastes used as fine/coarse aggregates on the properties of concrete were investigated by an in-depth literature review. Thus, the effect of these ceramic wastes on the durability and mechanical properties of concrete and mortar were presented in a detailed manner. Consequently, the use

of ceramic wastes and their effects as fine/coarse aggregates in a sustainable concrete and mortar were examined.

2. Methodology

In this study, considering the previous studies, mechanical and durability properties of concrete produced by waste ceramic addition into mortar and concrete investigated in detailed manner. Throughout the literature review, it was observed that ceramic waste was used as fine/coarse aggregate in sand/gravel in producing mortar/concrete mix. In these studies, effects of waste ceramic on the some mechanical and durability properties of concrete were investigated. In this study, mechanical properties grouped into compressive, flexural and tensile strength, elastic modulus and finally shrinkage of concrete. In addition to, durability properties grouped into water absorbtion, ultrasonic pulse velocity, chloride penetration, abrasion resistance and finally freeze-thaw resistance. Consequently, effects of waste ceramic on these properties of concrete were evaluated in a detailed manner and reasons of results were established.

3. Results and Discussion

3.1. Mechanical Properties

Mechanical properties of results were summarized in Table 1. Considering the results, waste ceramic was used as fine or/and coarse aggregate in concrete/mortar mixing. When ceramic waste was used as fine or/and coarse aggregate in concrete or mortar mixing, strength properties of concrete were increased compared with control concrete/mortar in generally. This improved incorporation of waste ceramic aggregate in the paste can be due to the more irregular shape it presents, resulting in a superior specific surface area than natural aggregate (gravel), which is rounded and thus lacks edges. Moreover, this irregular shape provides the higher bond between recycled ceramic aggregate and the paste. Furthermore, the ceramic aggregate could presented little puzzolanic activity in the surface part due to its chemical composition and grain size, this was nevertheless sufficient to react with the porltandite present in the periphery of the aggregate, giving rise to hydrated products such as calcium silicate hydrates (CSH) and calcium aluminate hydrates which present a less porous, more compact structure, forming a more stable aggregate/paste transition zone [4]. In contrast to all these studies, a few studies consisted of low strength properties compared to conventional concrete/mortar detected [5]-[6]. In these studies, the reason of strength loss was explained as ceramic aggregate having lower density and strength compared to conventional aggregate [6].

3.2. Durability Properties

Durability properties of results were summarized in Table 2. According to results of studies, chloride penetration, capillarity water absorbtion, abrasion resistance, freeze-thaw resistance, high temperature resistance, gas permeability and finally, ultrasonic pulse velocity properties were investigated in previous studies. Especially, capillary water absorbtion, oxygen and gas permeability of concrete produced waste ceramic as fine/coarse aggregate were improved or similar compared to conventional concrete. But, these properties were determined as worse compared to control specimen [7]-[8]. This decrease can be due to both the higher water absorption coefficient in waste ceramic aggregate and the effect of this waste ceramic aggregate on the pore system [9]. In generally, freeze-thaw durability and high temperature resistance, chloride penetration and abrasion resistance performance of concrete produced by waste ceramic were better than conventional concrete due to the high mechanical and the puzolonic properties of the ceramic aggregate [4].

Table 1. Comparison of some results for mechanical properties.

		Mixing Ratio of Concrete						
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Curing Day**	**Mechanical Property Findings**	**Ref.**
Normal Mortar Mixing	As Fine Aggregate in Sand	Earthenware ceramic waste (CWA)	(10-20-30-40-50-100)%	Mortar mix produced by %100 natural sand	-Compressive Strength	7, 14 and 28	All mortar mixes containing CWA gave higher compressive strength than that of the control mortar (42.2 MPa at 28 days), and that the compressive strength increased with increasing use of CWA up to 50% by weight (50.2 MPa at 28 days).	[10]
Normal Mortar Mixing	As Fine Aggregate in Sand	Porcelain insulator waste (CWA)	100%	Mortar mix produced by %100 typical river sand (RS)	-Compressive Strength	7, 28, 91	The compressive strength of the CWA mortars in which the CWA was used as received from the recycle plant was relatively similar to that of the corresponding RS mortars.	[11]
Conventional Concrete	As Fine Aggregate in Sand	Earthenware ceramic waste (CWA)	(50-100)%	Concrete mix produced by %100 natural sand	-Compressive Strength	7 and 28	The compressive strength at 28 days of (CWA) concrete increased with the use of CWA at 50% by weight, where it reached optimum strength (40 MPa). This was an increase of 7.5% compared to the control concrete. Thereafter a decline in compressive strength was observed, with a slightly lower value (38.5 MPa) at 100% CWA.	[10]
Conventional Concrete	As Fine Aggregate in Sand	White ceramic powder	(10-20-30-40-50)%	Concrete mix produced by %100 natural sand	-Compressive Strength -Tensile (Brazilian) Test -Flexi-traction Test	7, 14, 28	The use of white ceramic powder to substitute part of the sand does not reduce compressive strength but rather gives an appreciable increase in strength. Regarding traction resistance, the introduction of white ceramic powder does not give any appreciable difference compared with the control concrete.	[12]
Conventional Concrete	As Fine Aggregate in Sand	Crushed ceramic waste (CC)	(40- 50-60)%	Concrete mix produced by %100 conventional crushed fine aggregates	-Compressive Strength	7, 28, 90, 365	It can be seen that the compressive strength of CC concrete mixes with 40%, 50% and 60% fine aggregate replacement with CC were higher than the control specimen at all ages .However, the rate of increase of strength decreases with the increase in CC content.	[13]
Conventional Concrete	As Fine Aggregate in CEN Reference Sand	Sanitary ceramic waste	(10, 15 and 20)%	Concrete mix produced by %100 natural sand	-Compressive Strength -Flexural Strength	2, 7, 14, 28 and 56	Incorporation of ceramic waste aggregates led to a systematic improvement of the mechanical properties, the benefits increasing with the addition rate.	[14]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Brick, blocks and roof tiles - wall, floor tiles and sanitary ware	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Compressive Strength	7, 14, 28, 56 and 90	The results obtained indicate that the strength is higher for concrete with both replacements coarse ceramic aggregate and ceramic sand than control concrete with traditional aggregates.	[15]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Sanitary ceramic ware waste	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Compressive Strength -Tensile Strength	28	Compressive strength of such concrete was higher of 12% and tensile strength of 30% in comparison to concrete with sand and gravel aggregate.	[16]

Table 1. Comparison of some results for mechanical properties (cont.).

		Mixing Ratio of Concrete						
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Curing Day**	**Mechanical Property Findings**	**Ref.**
High-Performance Concrete	As Fine and coarse aggregate in sand and gravel	Earthenware ceramic waste	15-30% of natural sand and 20-50-100% of coarse mixed aggregates.	Concrete mix produced by %100 natural river sand mixes and dolomitic gravel	-Compressive Strength -Flexural Strength -Split Tensile Strength -Elastic Modulus	1, 7, 28 and 180	Concrete made with fine ceramic aggregate achieved a higher compressive, flexural, splitting tensile strength and elastic modulus strength in comparison to that of control concrete. But, the concrete made with more than 20% of coarse ceramic aggregates achieved a lower compressive, flexural, splitting tensile strength and elastic modulus to that of control concrete.	[8]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(15, 20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Compressive Strength -Split Tensile Strength	7, 28 and 90	The mechanical behavior, both in terms of compression and splitting tensile strength, was better for the recycled concretes than for the reference concrete.	[4]
Conventional Concrete	As Coarse Aggregate	Ceramic Waste	100%	Concrete mix produced by %100 conventional coarse aggregate	-Compressive Strength	28	The concrete mixes containing recycled ceramic waste aggregates achieve strength levels between 80 to 95% compared to the conventional concrete.	[17]
Conventional Concrete	As Coarse Aggregate	Ceramic electrical insulator wastes	100%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Compressive Strength -Flexural Strength -Split Tensile Strength -Elastic Modulus	28	The compressive, splitting tensile and flexural strengths of ceramic waste coarse aggregate concrete are lower by 3.8, 18.2 and 6% respectively when compared to conventional concrete, but ceramic waste coarse aggregate concrete possesses lower tensile to compressive strength ratio.	[18]
Conventional Concrete	As Coarse Aggregate	Crushed tiles	(50-100)%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Compressive Strength -Flexural Strength -Split Tensile Strength	7, 28	In general, concretes made with crushed tile as coarse aggregate showed higher compressive, tensile, and flexural strengths than control concrete.	[19]
Non-Structural Concrete	As Coarse Aggregate	Ceramic hollow bricks	(33, 66 and 100)%	Concrete mix produced by %100 coarse limestone aggregate	-Compressive Strength -Flexural Strength	28	The compressive and flexural strength, decreased with the percentage of replacement of limestone aggregates with ceramic aggregates increase. The decrease in compressive strength is higher than that in the flexural strength.	[6]
Portland Blast Furnace Cement Type B Concretes	As Coarse Aggregate	Porous ceramic waste aggregate (PCA)	(10 and 20)%	Concrete mix produced by %100 crushed gravel aggregate	-Compressive Strength -Shrinkage	3, 7 and 28 (internal curing)	A 10% replacement of coarse aggregate by PCA was more effective in improving compressive strength than a 20% replacement by PCA at the early ages of 3 and 7 days, independent of exposure conditions. Internal curing using PCA to replace part of the coarse aggregate was not effective in reducing autogenous shrinkage.	[20]

Table 2. Comparison of some results for durability properties.

Type of Product	Using of Waste Ceramic In The Concrete	Mixing Ratio of Concrete: Waste Ceramic Type	Mixing Ratio of Concrete: Waste Ceramic Ratio	Comparison Criteria	Experiments	Durability Results	Ref.
Normal Mortar Mixing	As Fine Aggregate in Sand	Porcelain insulator waste (CWA)	100%	Mortar mix produced by %100 typical river sand (RS)	-Chloride Penetration	It quantitatively indicated that the CWA mortars had lower apparent chloride diffusion coefficient than the RS mortars	[11]
Conventional Concrete	As Fine Aggregate in Sand	Crushed ceramic waste (CC)	(40- 50-60)%	Concrete mix produced by %100 conventional crushed fine aggregates	-Abrasion Resistance -Chloride Penetration	Abrasion resistance of concrete was strongly influenced by its compressive strength and crushed ceramic. Measurement of chloride penetration depths correlated well with the differences between additive type and replacement percentage of the mixtures. Crushed ceramic 60% specimens were considerably more resistant to chloride ingress than those of other specimens.	[13]
Conventional Concrete	As Fine Aggregate in CEN Reference Sand	Sanitary ceramic waste	(10, 15 and 20)%	Concrete mix produced by %100 natural sand	-Freeze-Thaw Resistance	The freeze-thaw resistance results were concluding that ground ceramic waste addition did not have any influence on compressive strength up to 25 cycles, the observed behavior being similar for all tested mortars. Conversely, freeze-thaw was found to affect negatively the flexural strength of all tested mortars, the reduction increasing with the ceramic waste content.	[14]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Sanitary ceramic ware waste	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-High Temp. Resist. -Abrasion Resistance	Abrasion resistance of concrete with ceramic sanitary ware aggregate is higher by about 20% than abrasion resistance of gravel concrete. Compressive strength of concrete with ceramic aggregate decreased immediately after heating by 46%, in comparison to strength of unheated concrete, whereas tensile strength decreased by 54%; strength loss was similar to other types of concrete, however high initial strength made the strength of this concrete still high after heating.	[16]
Conventional Concrete	As Fine and coarse aggregate in sand and gravel	Brick, blocks and roof tiles - wall, floor tiles and sanitary ware	100% (for both fine and coarse)	Concrete mix produced by %100 natural fine and coarse aggregate	-Capillary Water Absorb. -Oxygen Permeability -Chloride Penetration	As for capillarity water absorption coefficients the differences are rather important since capillary water absorption for control concrete (with traditional aggregates) almost doubles the capillarity water absorption coefficient of ceramic aggregates based concrete. The oxygen permeability results confirm the good performance of the concrete mixtures with ceramic aggregates. As for the chloride diffusion it once more confirms the good performance of ceramic sand and coarse ceramic aggregate based concrete.	[15]
High-Performance Concrete	As Fine and coarse aggregate in sand and gravel	Earthenware ceramic waste	15-30% of natural sand and 20-50-100% of coarse mixed aggregates.	Concrete mix produced by %100 natural river sand mixes and dolomitic gravel	-Ultrasonic Pulse Veloc. -Capillary Water Absorb. -Chloride Penetration	Although the capillary absorption coefficient and ultrasonic pulse velocity values were worse than those of conventional concrete, the chloride ion penetration, after 180 days, was lower in concretes made with ceramic fine aggregates.	[8]

Table 2. Comparison of some results for durability properties (cont.).

		Mixing Ratio of Concrete					
Type of Product	**Using of Waste Ceramic In The Concrete**	**Waste Ceramic Type**	**Waste Ceramic Ratio**	**Comparison Criteria**	**Experiments**	**Durability Results**	**Ref.**
Non-Structural Concrete	As Coarse Aggregate	Ceramic hollow bricks	(33, 66 and 100)%	Concrete mix produced by %100 coarse limestone aggregate	-Capillary Water Absorb. -Immersion Water Absorb -Abrasion Resistance	The durability of this type of concrete may turn out to be its major insufficiency, since water absorption either by immersion or capillarity increases very regularly and significantly with the proportion of ceramic aggregates on the concrete mix. Abrasion resistance is precisely the one in which the concrete produced with recycled ceramic aggregates shows an excellent performance, even better than the reference concrete.	[21]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Gas Permeability	According to test results, micro-porosity and gas permeability, O_2 and CO_2 permeability were similar in the reference concrete and the concretes containing recycled sanitary ware as a partial replacement for conventional aggregate.	[7]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Freeze-Thaw Resistance	Sanitary ware industry aggregate is more resistant to temperature change than natural coarse aggregate. The new concrete is more freeze-thaw resistant than conventional concrete. The scaling rate is lower and the cracks are narrower in recycled concrete. Both effects are accentuated with rising replacement ratios.	[9]
Conventional Concrete	As Coarse Aggregate	Sanitary ceramic waste	(20 and 25)%	Concrete mix produced by %100 natural coarse aggregate.	-Water Resistance -Porosity -Sorptivity	The maximum depth of water penetration is no greater in recycled aggregate than natural aggregate concretes, and although the average value is somewhat higher in the former, it never exceeds 30 mm. The inclusion of ceramic sanitary ware aggregate raises total porosity slightly and modifies pore size distribution, with an increase in the volume of capillary pores at the expense of macro pores. The concretes with recycled ceramic aggregate have greater sorptivity than conventional concretes, since the values are consistently under 3 mm/h$^{0.5}$, these may consequently be regarded as durable materials.	[4]
Conventional Concrete	As Coarse Aggregate	Ceramic electrical insulator wastes	100%	Concrete mix produced by %100 conventional crushed stone coarse aggregate	-Capillary Water Absorb. -Sorptivity -Chloride Penetration	The basic trend of permeation characteristics of the ceramic electrical insulator waste coarse aggregate concrete is similar to those of the conventional concrete. The permeation characteristic values increase with increase in water–cement ratio for both the ceramic electrical insulator waste coarse aggregate concrete and the conventional concrete.	[18]

4. Conclusions

In this study, effects of waste ceramic on some mechanical and durability properties of conventional concrete were investigated. Considering all of the results and the findings in the literature, it was found that, using of waste ceramic in the conventional concrete as fine/coarse aggregate was positively affected on these mechanical and durability properties of concrete. Consequently, the green and sustainable concretes would be obtained by partial substitution of waste ceramic aggregates from different ceramics industry can be used for structural purposes.

References

[1] F. Puertas, M. T. Blanco-Varela, and T. Vazquez, "Behavior of cement mortars containing an industrial waste from aluminum refining Stability in $Ca(OH)_2$ solutions," Cement and Concrete Research, vol. 29, pp. 1673-1680, 1999.

[2] M. Fernandes, A. Sousa, and A. Dias, "Environmental impact and emissions trade ceramic industry- A case study," Portuguese Association of Ceramic Industry APICER, Portuguese, 2004.

[3] F. Pacheco-Torgal, and S. Jalali, "Compressive strength and durability properties of ceramic wastes based concrete," Materials and Structures, vol. 44, pp. 155-167, 2011.

[4] C. Medina, M. I. Sanchez de Rojas, and M. Frias, "Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes," Cement & Concrete Composites, vol. 34, pp. 48-54, 2012.

[5] R. M. Senthamarai, and P.D. Manoharan, "Concrete with ceramic waste aggregate," Cement & Concrete Composites, vol. 27, pp. 910-913, 2005.

[6] J. Brito, A.S. Pereira, and J.R. Correia, "Mechanical behaviour of non-structural concrete made with recycled ceramic aggregates", Cement & Concrete Composites, vol. 27, pp. 429-433, 2004.

[7] C. Medina, M. Frias, M. I. Sanchez de Rojas, C. Thomas, and J.A. Polanco, "Gas permeability in concrete containing recycled ceramic sanitary ware aggregate," Construction and Building Materials, vol. 37, pp. 597-605, 2012.

[8] A. Gonzalez-Corominas, and M. Etxeberria, "Properties of high performance concrete made with recycled fine ceramic and coarse mixed aggregates," Construction and Building Materials, vol. 68, pp. 618-626, 2014.

[9] C. Medina, M. I. Sanchez de Rojas, and M. Frias, M, "Freeze-thaw durability of recycled concrete containing ceramic aggregate," Journal of Cleaner Production, vol. 40, pp. 151-160, 2013.

[10] P. Torkittikul, and A. Chaipanich, "Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes," Cement & Concrete Composites, vol. 32, pp. 440-449, 2010.

[11] H. Higashiyama, K. Yamauchi, M. Sappakittipakorn, M. Sano, and O. Takahashi, "A visual investigation on chloride ingress into ceramic waste aggregate mortars having different water to cement ratios," Construction and Building Materials, vol. 40, pp. 1021-1028, 2013.

[12] V. Lopez, B. Llamas, A. Juan, C.M. Moran, and I. Guerra, "Eco-efficient concretes: impact of the use of white ceramic powder on the mechanical properties of concrete," Biosystems engineering, Vol. 96, pp. 559-564, 2007.

[13] H. Binici, "Effect of crushed ceramic and basaltic pumice as fine aggregates on concrete mortars properties," Construction and Building Materials, vol. 21 pp. 1191-1197, 2007.

[14] W. Jackiewicz-Rek, K. Załęgowski, A. Garbacz, and B. Bissonnette, "Properties of cement mortars modified with ceramic waste fillers," Procedia Engineering, vol. 108, pp. 681-687, 2015.

[15] F. Pacheco-Torgal, and S. Jalali, "Reusing ceramic wastes in concrete," Construction and Building Materials, vol. 24, pp. 832-838, 2010.

[16] A. Halicka, P. Ogrodnik, and B. Zegardlo, "Using ceramic sanitary ware waste as concrete aggregate," Construction and Building Materials, vol. 48, pp. 295-305, 2013.

[17] A.M.M. Al Bakri, M. N. Norazian, H. Kamarudin, M.A.A. Mohd Salleh, and A. Alida, "Strength of concrete based cement using recycle ceramic waste as aggregate," Advanced Materials Research, vol. 740, pp. 734-738, 2013.

[18] R.M. Senthamarai, P.D. Manoharan, and D. Gobinath, "Concrete made from ceramic industry waste: Durability properties," Construction and Building Materials, vol. 25, pp. 2413-2419, 2011.

[19] A.R. Khaloo, "Crushed Tile Coarse Aggregate Concrete," Cement, Concrete, and Aggregates, vol. 17, pp. 119-125, 1995.

[20] R. Sato, A. Shigematsu, T. Nukushina, and M. Kimura, "Improvement of properties of portland blast furnace cement type b concrete by internal curing using ceramic roof material waste," Journal of Materials in Civil Engineering, vol. 23, PP. 777-782, 2011.

[21] J.R. Correia, J. Brito, A.S. Pereira, "Effects on concrete durability of using recycled ceramic aggregates," Materials and Structures, vol. 39, pp. 169-177,2006.

BIBLIOGRAPHY OF AUTHORS

Gülden Çağın Ulubeyli was born on November 3rd of 1982 in Bursa, Turkey. She completed her primary and middle school educations in Erzurum. Following her high school education in Erzurum High School in 2000, she was graduated from Civil Engineering Department of Atatürk University in 2006 and Chemical Engineering Department in 2007. She graduated her M.Sc. education at Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, Metallurgy and Materials Engineering Program in 2011. She is currently studying her PhD. education at Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, Metallurgical and Materials Engineering Program since 2011. Also, she has been working as a Research Assistant in Civil Engineering Department of Bulent Ecevit University since 2009.

Turhan Bilir is an Associate Professor and the Head of the Department of Civil Engineering Bülent Ecevit University, Zonguldak, Turkey. He worked for Department of Civil Engineering Bülent Ecevit University as an Assistant Professor between 2011 and 2014. He received his BSc degree from Eskisehir Osmangazi University at 2001, his MSc degree from Zonguldak Karaelmas University at 2005 and his PhD. degree from Eskisehir Osmangazi University at 2010. His research interests include durability of cement and concrete, the use of wastes and by-products in the cement and concrete industry, composite materials and models, lightweight aggregates and concrete, sustainable development in cement and concrete industry, and restraint drying shrinkage of concrete.

Recep Artır is a lecturer and Professor of Metallurgical and Materials Engineering. He received his BSc degree in Metallurgical Engineering from İstanbul Technical University, Turkey in 1985. He received his MSc degree in Metallurgical Engineering from Yıldız University, İstanbul, Turkey in 1988 and his PhD. degree from Sheffield University in 1994 in the UK. Currently, he carries out his teaching and research activities in Metallurgical and Materials Engineering department at Marmara University. His research interests include iron and steel production, recycling of industrial wastes, ceramic and refractory materials, biomaterials and surface modification of materials.